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FINAL TECHNICAL REPORT

United States Air Force Office of Scientific Research

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# "ELECTROMAGNETIC SCATTERING PROCESSES AT RESONANCES AND WITH INTENSE FIELDS"

Principal Investigator
Robert W. Hellwarth
University of Southern California

Period of work: 2/1/79 to 7/31/80

AFOSR-TR- 80-1783

1. Research Objectives:

To be able to interpret and predict the nature of the electromagnetic radiation that is scattered by matter from a strong incident monochromatic wave whose frequency is at or near a resonance of the scattering medium. The problems attacked include those that arise in mode-locking, saturable absorption, saturation spectroscopy, high-energy optical amplifiers, infrared-laser window failure, optical image and frequency converters, optical computers, and coherent optical adaptive techniques.

2. Approach:

Our approach is mainly theoretical and directed toward the needs of experimenters currently utilizing resonant laser-matter interactions (tunable and high-power laser sources, detectors, etc.). Some experimentation was also performed in support of the theoretical studies.

3. Progress and Major Results Achieved (2/1/79-7/31/80):

3.1. From theoretical studies of the vibrational modes of transparent glasses, we discovered a property which could have profound affect on the propagation in some glasses of strong electromagnetic waves. This property, which is result of the naturally occuring anharmonicity

in inter-atomic forces in the glass lattice, can give rise to such effects as (a) broadband optically-pumped gain in the infrared, (b) infrared-photon echoes, and (c) saturable infrared abosrption. Details are given in Appendix I.

3.2. The theory of the effects of linear absorption on optical-beam phase conjugation by stimulated Brillouin scattering was completed. The results of this theory will be incorporated in a chapter (contributed by R.W. Hellwarth) of the book "Optical phase conjugation", edited by R.A. Fisher and to be published in 1981 by Academic Press.

3.3. The enhancement near resonance of optical phase conjugation produced by stimulated Raman and Brillouin scattering was studied. Preliminary results were not promising for application.

3.4. The effects of different states of optical beam polarization on phase-conjugation by stimulated scattering were studied. It was found that phase-conjugation is spoiled if the input beam is not uniformly polarized linearly or circularly, and if this polarization is not maintained in linear propagation through the interaction region. The results of this study will also appear in the aforementioned Academic Press book chapter.

3.5. Studies were initiated on the possibilities of simultaneous pulse compression and phase-conjugation in stimulated backscattering, in the limit where the incident field is so strong as to make the small-signal steady state gain per cm much larger than the excitation damping rate times the velocity of light. This very high gain (VHG) regime has not been studied previously and shows great promise for optical pulse-compression with phase conjugation.

3.6. A first experimental attempt was made to perform a novel form of polarization spectroscopy in which the polarization of a phase-conjugation signal is altered when its frequency is near resonance. The attempt, made with a refurbished $N_2$-pumped R6G dye laser in sodium vapor, was inconclusive, but promising. Strong self-focusing and defocusing hampered observations.

4. Talks and Publications:

4.1. "Conjecture on the effect of small anharmonicity on vibrational modes of glass", R.W. Hellwarth, Solid State Comm., vol. 32, pp. 85-88 (1979). Attached as Appendix I.

4.2. "Wavefront conjugation: general principles", R.W. Hellwarth. Invited paper at the meeting on "Ultrashort laser pulses" of the Royal Society, London, England, 23 May, 1979.

4.3. M.I.T. Seminar in Modern Optics and Spectroscopy Series: "Optical beam phase conjugation by stimulated scattering and wave mixing", March 1, 1980.

5. Personnel Supported:

Principal Investigator: R.W. Hellwarth

Postdoctoral Research Associates: G. Martin, D. Kirillov, and S. Jabr.

Doctoral Candidate: T. Chang

Secretary: P. Johnson